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THE VARIOUS B. T. U. VALUES OF A COAL

BY

J. F. BARKLEY AND L. R. BURDICK

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

THE VARIOUS B. T. U. VALUES OF A COAL[1]

By J. F. Barkley[2] and L. R. Burdick[3]

INTRODUCTION

The inherent heating value or the amount of heat that will be produced when a coal is completely burned is measured in British thermal units (B. t. u.) per pound of coal. This standard heat unit is the quantity of heat required to raise the temperature of 1 pound of water 1°F. at about 60°F. The amount of inherent heat is determined by burning a small quantity of the coal in a heat meter or calorimeter, which gives results in British thermal units. The exact manner of making this test is standardized by the American Society for Testing Materials.[4]

The value so determined is the total heat developed by complete burning, with all the products of combustion cooled down to the temperature of the calorimeter. The calorimeter is kept at about room temperature. This total heat is sometimes called the "high" or gross heat value, because it includes the latent heat given up by the water vapor in the products of combustion when the vapor condenses to water in the calorimeter. The heat as measured is reported as the heat of combustion at constant volume, since the burning is carried out in a tightly closed calorimeter chamber whose volume does not change. In actual use, coal is usually burned in an open-end chamber at constant pressure, generally somewhere near atmospheric. As the heat of combustion of coal at constant pressure is very slightly higher than the heat of combustion at constant volume, it might be considered that the heat at constant pressure should be used as the standard reference base. For an ordinary eastern coal the heat at constant pressure is about 16 B. t. u. per pound higher than the heat at constant volume. Calorimeter corrections, ordinarily not considered, that could have been subtracted from the heating value before reporting, may amount to about as much. Hence, the value reported is apt to be more nearly the true heating value at constant pressure than at constant volume.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7193."

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[4] American Society for Testing Materials, Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D271-40): A.S.T.M. Standards on Coal and Coke, December 1940, pp. 31-35.

The chemical elements in coal that produce essentially all the heat are carbon, hydrogen, and sulfur. Therefore, the B. t. u. value of a coal as shown by the calorimeter may be approximated by computation from Dulong's formula:

$$\text{B. t. u. per lb.} = 14{,}544\ C + 62{,}028\ (H - \frac{O}{8}) + 4{,}050\ S,$$

where C, H, O, and S represent the quantities fractions of a pound) of carbon, hydrogen, oxygen, and sulfur in 1 pound of coal. One pound of each element is considered to produce the quantity of heat expressed by the number preceding it in the formula. It is assumed that all oxygen in the coal is combined with hydrogen in the ratio of 8:1 to form water (H_2O); hence, only the remaining uncombined hydrogen is available for producing heat. For anthracite, semianthracite, and bituminous coals the computed B. t. u. values are usually within 1-1/2 percent of the values determined by the calorimeter. For subbituminous and lignitic coals the computed values often deviate as much as 5 percent. Causes for these differences include: (1) The heating values given by the numbers in the formula may not be quite correct for the conditions; (2) all the oxygen may not be combined with hydrogen, as part may be combined with other substances, such as carbon; (3) the percentage of oxygen in coal is determined by subtracting the sum of all the other substances found by analysis from 100 percent, thus throwing all errors into the percentage of oxygen; and (4) the production of heat from coal is not as simple as the formula indicates since various heat reactions occur with other substances in the coal, such as the burning of the iron in the ash. The usefulnesss of the Dulong formula is quite limited. It is much simpler and cheaper to make a calorimeter test than to analyze for the various chemical elements in the coal. Formulas have been proposed at various times for the calculation of the heating value from the "proximate" analysis of the coal. The proximate analysis gives the moisture, volatile matter, fixed carbon, and ash. Such formulas are apt to give unreliable results.

VARIOUS B. T. U. VALUES OF COAL

There are various ways of considering the B. t. u. value of coal. It is ordinarily expressed as the B. t. u. per pound: (1) "As received" or "as sampled"; (2) "moisture free" or "dry"; (3) "moisture- and ash free"; (4) "H" value; (5) dry, "mineral matter free"; (6) moist, "mineral matter free". For any one coal sample, all these values are related by values of the chemical analysis of the coal. If the moisture, ash, and sulfur contents are known, any one of these values may be calculated from any other.

As-received and Dry B. t. u.

The as-received or as-sampled B. t. u. is the heat in 1 pound of coal as found or as ordinarily purchased. The moisture free or dry B. t. u. is the heat in 1 pound of coal after the moisture has been removed by a standardized method in which the coal is dried at a temperature above the boiling point of water, or about 225°F.[5] This drying not only removes the surface moisture that can be seen on the coal (sensible moisture) but also moisture that is so closely held by the coal (inherent moisture) that it does not produce wetness. The total moisture varies from time to time for the same coal, being affected by the weather and periods of drying. Although "dry" coal does not really exist except in the laboratory, the dry B. t. u. is a more stable value and is also convenient for comparing different coals. As the moisture has no heat value and merely dilutes the coal, 1 pound of dry coal would have a higher heating value than 1 pound of a mixture of the dry coal and moisture; the difference between the two values would vary directly with the amount of moisture. For example, assume a coal "as received" had a B. t. u. of 13,170 per pound and a moisture content of 4.9 percent. The B. t. u. per pound dry would equal:

$$\frac{13{,}170 \text{ B. t. u. ``as received''}}{\begin{array}{l}1.000 - 0.049 = 0.951 \text{ pound}\\ \text{(dry coal supplying the heat}\\ \text{ in the mixture)}\end{array}} = 13{,}850 \text{ B. t. u. ``dry,''}$$

or

$$13{,}850 \text{ B. t. u. ``dry''} \times 0.951 = 13{,}170 \text{ B. t. u. ``as received.''}$$

Moisture- and Ash-free B. t. u.

The moisture- and ash-free B. t. u. is the heat in 1 pound of the coal when not only the moisture but also the ash is removed. Ash as reported from the laboratory is also a diluent and as such supplies no heat. The ash varies in amount, depending on the mining and cleaning of the coal. The moisture- and ash-free B. t. u. would represent a still more stable value and tend to give the heating value of the "pure" coal substance. If the coal used in the foregoing example had an ash content of 10.0 percent on the as-received basis (or $\frac{10.0}{0.951}$ = 10.5 percent on the dry basis), the moisture- and ash-free B. t. u. would equal:

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[5] American Society for Testing Materials, Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D271-40): A.S.T.M. Standards on Coal and Coke, December 1940, pp. 9-15.

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$$\frac{13{,}170 \text{ B. t. u. ``as received''}}{1.000 - (0.049 + 0.100) = 0.851 \text{ pound (coal substance free from moisture and ash)}} = 15{,}480 \text{ B. t. u. moisture and ash free,}$$

or

$$\frac{13{,}850 \text{ B. t. u. ``dry''}}{1.000 - 0.105 = 0.895} = 15{,}480 \text{ B. t. u. moisture and ash free,}$$

or

15,480 B. t. u. "moisture and ash free" x 0.851 = 13,170 B. t. u. "as received,"

or

15,480 B. t. u. "moisture and ash free" x 0.895 = 13,850 B. t. u. "dry"

"H" B. t. u.

The "H" B. t. u.[6] value of coal was originated to express a heating value of "pure" coal that did not include the heat produced by the sulfur in the coal. It was considered that the heating value of the "pure" coal in a given mine or seam might be fairly constant and that the sulfur was a contamination of the "pure" coal that had been added in variable amounts to the original coal. The "H" value was derived from the "as received" or "dry" B. t. u. by first subtracting the heat of the sulfur, taken as 4,050 B. t. u. per pound. Assuming the coal used in the preceding example had a sulfur content of 1.9 percent as received (or 2.0 percent on the dry basis) then:

$$\frac{13{,}170 \text{ B. t. u. ``as received''} - 4{,}050 \times 0.019 \text{ pound (sulfur)}}{1.00 - (0.049 + 0.100 + 0.019) \text{ or } 0.832 \text{ pound (coal substance free from moisture, ash, and sulfur)}} = 15{,}740 \text{ B. t. u. ``H'' value,}$$

or

$$\frac{13{,}850 \text{ B. t. u.} - 4{,}050 \times 0.02}{1.00 - (0.105 + 0.02) \text{ or } 0.875} = 15{,}740 \text{ B. t. u. ``H'' value.}$$

Dry, Mineral-matter-free B. t. u.

The dry, mineral-matter-free B. t. u. value was later devised to express more nearly the correct B. t. u. value for "pure" coal.[7]

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[6] Lord, N.W., and Haas, F., The Calorific Value of Certain Coals as Determined by the Mahler Calorimeter: Trans. Am. Inst. Min. Eng., vol. 27, 1897-98, p. 259.

[7] Parr, Samuel W., The Classification of Coal: Univ. of Illinois Eng. Exper. Sta. Bull. 180, July 31, 1928.

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Instead of considering the noncoal part to be merely the sum of the moisture, ash, and sulfur from the analysis, it was determined as follows:

$$\text{Noncoal} = \text{moisture} + \text{ash} + 5/8 \text{ sulfur} + 0.08 \left(\text{ash} - \frac{10}{8} \text{ sulfur}\right).$$

This formula is based upon the fact that the quantity of ash reported in the usual coal analysis is not the true amount of mineral matter as it existed in the coal; it is the residue left after the coal is burned - a step in making the analysis.[8] This burning causes changes in the mineral matter. Before the coal is burned, it is assumed that the sulfur is united with iron to form iron sulfide (FeS_2). While the coal is burning, the sulfur burns to a gas and leaves the ash. The iron, however, unites with oxygen from the air, forming iron oxide (Fe_2O_3) which remains to form part of the ash; therefore, the oxygen increases the weight of the ash. For every pound of sulfur, three-eighths pound of oxygen is added to the ash; therefore, only five-eighths of the sulfur should be added to the ash as weighed to obtain the noncoal substance. The last expression of the formula, 0.08 (ash - $\frac{10}{8}$ sulfur), is used to approximate the water combined with earthy mineral matter in the coal. Certain forms of mineral matter of the coal, as clay or shale, lose water when heated to the higher temperatures. The weight of this water should also be included in the formula to obtain the true amount of noncoal substance. For every pound of sulfur, ten-eighths pound of iron oxide is formed in the ash. Subtracting ten-eighths sulfur from the ash as weighed, therefore, gives the quantity of earthy material that might have lost water; multiplying this by a chosen figure of 0.08 gives approximately the water lost by the original mineral matter.

The expression,

$$\text{Noncoal} = \text{moisture} + \text{ash} + 5/8 \text{ sulfur} + 0.08 \left(\text{ash} - \frac{10}{8} \text{ sulfur}\right),$$

can be simplified by combining:

$$\text{Noncoal} = \text{moisture} + 1.08 \text{ ash} + \frac{21}{40} \text{ S (or 0.525 S)}.$$

This expression was further simplified by changing the 0.525 to 0.55, giving the final expression:

$$\text{Noncoal} = \text{moisture} + 1.08 \text{ ash} + 0.55 \text{ S}.$$

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[8] American Society for Testing Materials, Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D271-40): A. S. T. M. Standards on Coal and Coke, December 1940, pp. 15-16.

The dry, mineral-matter-free B. t. u. value is derived from the as-received B. t. u. in a somewhat similar manner to the "H" value as follows:

$$\frac{13{,}170 \text{ B. t. u. (as received)} - 5{,}000 \times 0.019 \text{ pound (S)}}{1.00 - (0.049 + 1.08 \times 0.10 + 0.55 \times 0.019) \text{ or } 0.833 \text{ pound (``pure'' mineral-matter-free coal substance)}} = 15{,}700 \text{ B. t. u. dry, mineral matter free,}$$

or on the dry basis

$$\frac{13{,}850 - 5{,}000 \times 0.02 \text{ S}}{1.00 - (1.08 \times 0.105 + 0.55 \times 0.02) \text{ or } 0.876} = 15{,}700 \text{ B. t. u.}$$

In these calculations the quantity of heat produced by the sulfur to be subtracted from the calorimetric heat is 5,000 B. t. u. per pound instead of the 4,050 B. t. u. used in deriving the "H" value. This change for more accuracy is based on the fact that 4,050 B. t. u. is the heat of combustion of pure sulfur and, as already shown, when the sulfur burns the iron with which it is associated also burns, giving some heat not included in the 4,050 B. t. u. The 5,000 B. t. u. was chosen as more nearly representing the actual heat produced per pound of sulfur under the conditions in which it occurs in the coal.

Moist, Mineral-matter-free B. t. u.

The moist, mineral-matter-free B. t. u., as the name indicates, is the B. t. u. of 1 pound of the moist, "pure" coal substance. The value found in coal containing its natural bed moisture but not including visible water on its surface is used in coal-classification standards for determining the rank of certain coals of the bituminous, subbituminous, and lignitic classes.9/ It may be derived from the as-received B. t. u. as follows:

$$\frac{13{,}170 \text{ B. t. u. (as received)} - 5{,}000 \times 0.019 \text{ pound S}}{1.00 - (1.08 \times 0.100 + 0.55 \times 0.019) \text{ or } 0.882 \text{ pound}} = 14{,}830 \text{ B. t. u. moist, mineral-matter-fre}$$

The various B. t. u. values determined in the preceding examples for a coal having, on the as-received basis, a moisture content of 4.9 percent, an ash content of 10.0 percent, and a sulfur content of 1.9 percent follow:

9/ American Society for Testing Materials, Standard Specifications for Classification of Coals by Rank (D388-38): A. S. T. M. Standards on Coal and Coke, December 1940, pp. 83-88.

As-received or as-sampled B. t. u. = 13,170
Moisture-free or dry B. t. u. = 13,850
Moisture- and ash-free B. t. u. = 15,480
"H" value B. t. u. = 15,740
Dry, mineral-matter-free B. t. u. = 15,700
Moist, mineral-matter-free B. t. u. = 14,830

The range in these figures shows the necessity of defining just what "B. t. u. value" of a coal is being considered.

CONSTANCY OF MOISTURE- AND ASH-FREE B. T. U.

There is a general belief in the coal trade that the moisture- and ash-free B. t. u. of delivered coal, although varying for coals of different rank, is substantially constant for coal from the same seam, especially for coal from the same mine. If so, calculation of this value from the usual coal analysis and calorimetric B. t. u. value would reveal if a coal did not come from a given area or seam; for restricted areas, it would reveal its probable origin. Knowing the value for a given mine, it would be possible to determine the calorimetric B. t. u. of coal from that mine if the coal analysis were known or the amount of moisture and ash if the calorimetric B. t. u. were known.

For example, using the coal of the previous examples:

Coal analysis, percent

	As received	Dry
Moisture	4.9	
Volatile	25.0	26.3
Fixed carbon	60.1	63.2
Ash	10.0	10.5
	100.0	100.0
B. t. u.	13,170	13,850
Moisture- and ash-free B. t. u.		15,480

Coal analysis of coal from same mine, percent

	As received	Dry
Moisture	3.6	
Volatile	25.9	26.9
Fixed carbon	62.5	64.8
Ash	8.0	8.3
	100.0	100.0

On the as-received basis, the amount of moisture- and ash-free coal per pound of coal as received equals $1.00 - (\overset{\text{Moisture}}{0.036} + \overset{\text{Ash}}{0.080})$ or 0.884 pound.

$$15{,}480 \text{ (moisture- and ash-free B. t. u. per pound, the constant for that mine)} \times 0.884 = 13{,}680 \text{ B. t. u. as received.}$$

On the dry basis:

$$15{,}480 \times (1.00 - 0.083) \text{ or } 0.917 = 14{,}200 \text{ B. t. u. dry.}$$

If the as-received B. t. u. were known, the quantity of moisture and ash would be:

$$\frac{13{,}680}{15{,}430} = 0.884 \text{ pound}$$

1.000 - 0.884 = 0.116 pound per pound of coal; that is, the sum of the ash and moisture in percent would be 11.6 percent. On the dry basis:

$$\frac{14{,}200}{15{,}480} = 0.917 \text{ pound.}$$

1.000 - 0.917 = 0.083 pound, or 3.3 percent ash.

To determine the possible limitations or the accuracy of the idea of a constant moisture- and ash-free B. t. u., a study was made of many delivered coal analyses from the laboratories of the Bureau of Mines.[10] As the characteristics of coal from a given seam differ somewhat in different areas, it was considered that samples from the same mine would vary least in value. Thirteen mines were therefore chosen covering coals of many ranks, as shown in table I.

10/ For complete study, results, and mathematical development, see Barkley, J. F., and Burdick, L. R., Constancy of B. t. u. Value of "Pure" Coal: Bureau of Mines Rept. of Investigations 3572, 1941, 10 pp.

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TABLE I.- Typical analyses of coals studied

			Coal analysis					
			H_2O	Dry basis				
Mine No.	State	Rank		Vol.	F.C.	Ash	S	B.t.u.
1	Pennsylvania	Anthracite	4.5	4.8	84.6	10.6	0.7	13,430
2	do.	do.	2.2	7.2	80.7	12.1	1.1	13,400
3	Virginia	Semianthracite	1.2	12.4	64.9	22.7	.5	11,660
4	Pennsylvania	Low-volatile bituminous	2.7	16.7	74.4	8.9	1.3	14,250
5	do.	do.	3.6	18.2	74.4	7.4	.9	14,500
6	West Virginia	do.	3.0	20.4	75.3	4.3	.9	14,980
7	Pennsylvania	Medium-volatile bituminous	2.6	22.2	70.4	7.4	1.8	14,500
8	do.	do.	2.2	26.2	65.0	8.8	2.3	14,190
9	Kentucky	High-volatile A bituminous	3.5	36.2	49.1	14.7	4.4	12,540
10	West Virginia	do.	1.6	36.3	55.2	8.5	3.1	13,940
11	Illinois	High-volatile B bituminous	8.9	39.3	50.5	10.2	3.7	12,880
12	Wyoming	Subbituminous B	20.2	41.2	53.4	5.4	.6	12,370
13	North Dakota	Lignite	31.5	38.4	47.9	13.7	1.1	10,600

RESULTS

Studies were made not only of the moisture- and ash-free B. t. u. but also of the "H" value and the dry, mineral-matter-free B. t. u. Table II shows the average, highest, and lowest B. t. u. values for each mine. The range in values above and below the average is also given, together with the total range. Figure 1 shows these ranges graphically. The dotted lines indicate the range after eliminating a number of values farthest from the average; the number of values eliminated was arbitrarily chosen as 5 percent of the total number in each instance. In general, the range is about the same for the three ways of expressing B. t. u. values. The simpler, moisture- and ash-free value appears to serve as well as any other for most B. t. u. calculations.

Although the range in moisture- and ash-free values is rather large, particularly for the anthracites, the subbituminous coal, and the lignite, about 55 to 70 percent of the values for the bituminous coals fell within about 25 to 60 B. t. u. of the average.

For some estimating and survey purposes, the average moisture- and ash-free B. t. u. value is of interest. Table III lists these values for various coal seams and areas. The table also includes the corresponding dry, mineral-matter-free B. t. u. and dry, volatile-matter values. The values were derived from analyses of all mine and delivered samples recorded by the Bureau of Mines and also from other published analyses. Values marked (b) are averages of only 20 to 60 samples from sources other than the Bureau of Mines; those marked (c) are averages from these sources of less than 20 samples.

Figure 2 shows a plot of the dry volatile matter versus the moisture- and ash-free B. t. u. and also the mineral-matter-free B. t. u. A similar plot, using the moisture- and ash-free volatile matter gave a somewhat greater "scatter" effect.

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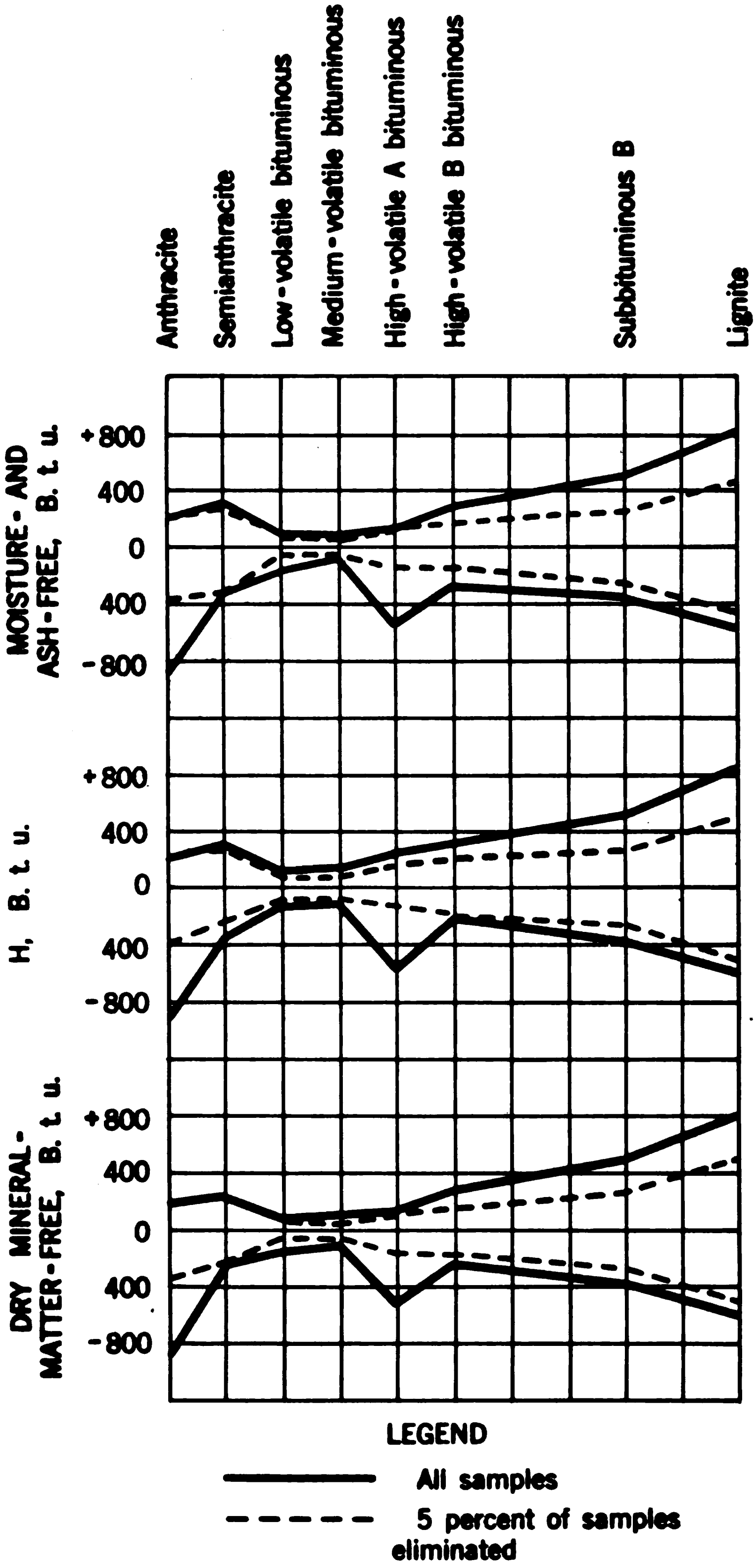

Figure 1.—Ranges of the various B. t. u. values of coals of different rank. The range for each rank is representative of coal from the same mine.

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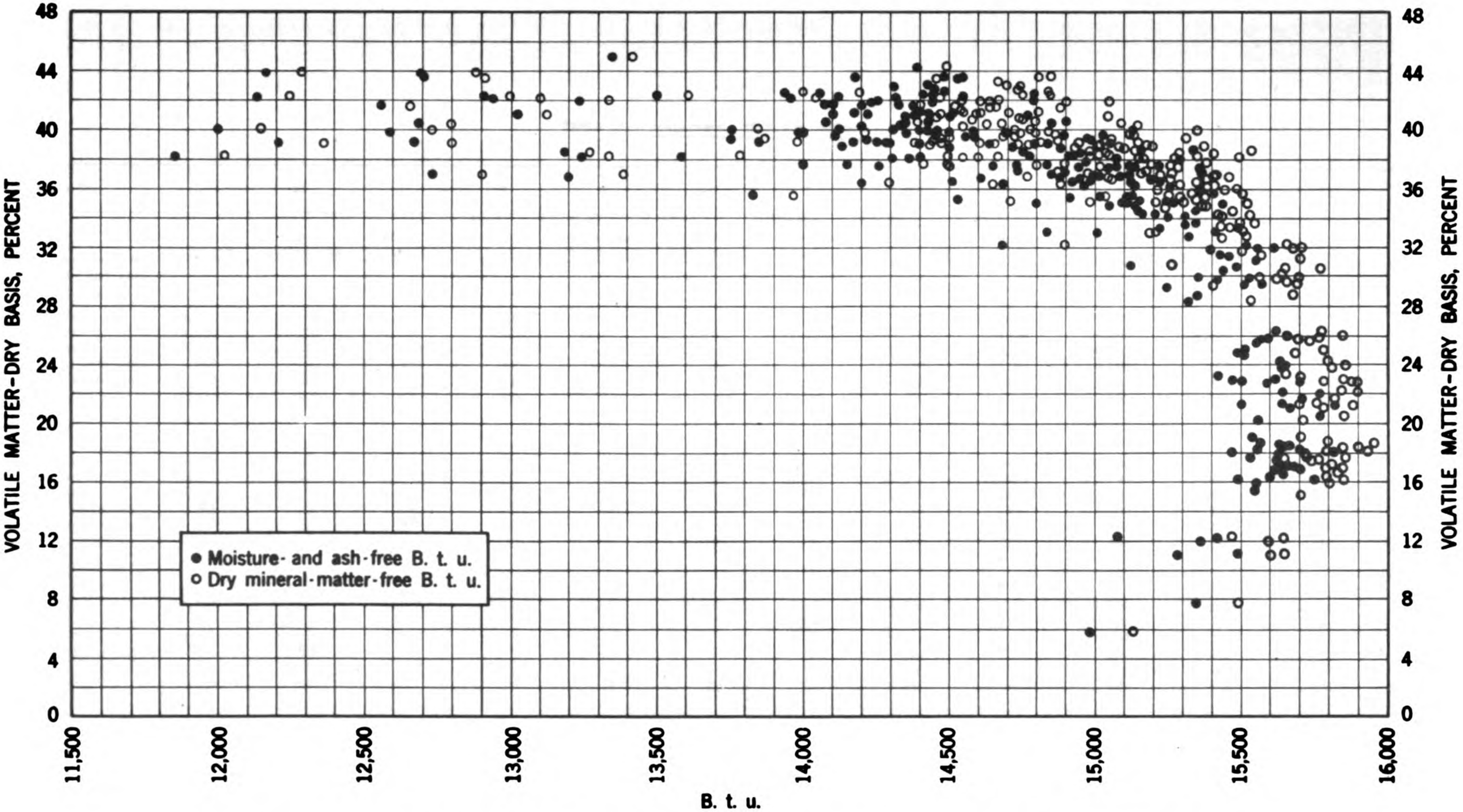

Figure 2.—Plat of percentage of dry volatile matter versus moisture- and ash-free B. t. u. and mineral-matter-free B. t. u.

TABLE II.- Comparison of B.t.u. values

Coal mine No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Rank	Anthracite	Anthracite	Semi-anthracite	Low-volatile bituminous	Low-volatile bituminous	Low-volatile bituminous	Medium-volatile bituminous	Medium-volatile bituminous	High-volatile A bituminous	High-volatile A bituminous	High-volatile B bituminous	Sub-bituminous B	Lignite
Moisture- and ash-free B. t. u.:													
Maximum	15,200	15,420	15,400	15,730	15,780	15,730	15,770	15,620	14,860	15,390	14,560	13,530	13,090
Average	14,950	15,250	15,080	15,620	15,650	15,660	15,670	15,530	14,720	15,240	14,270	13,030	12,280
Minimum	13,980	14,470	14,770	15,480	15,350	15,540	15,570	15,420	14,110	14,700	13,990	12,660	11,700
Range (above ave.	250	170	320	110	130	70	100	90	140	150	290	500	810
(below ave.	970	780	310	140	300	120	100	110	610	540	290	370	580
Total range	1,220	950	630	250	430	190	200	200	750	690	580	870	1,390
"H" value:													
Maximum	15,290	15,570	15,480	15,890	15,980	15,860	16,020	15,970	15,470	15,940	14,990	13,600	13,220
Average	15,040	15,380	15,160	15,780	15,800	15,770	15,900	15,810	15,280	15,640	14,680	13,090	12,380
Minimum	14,050	14,540	14,820	15,660	15,590	15,640	15,780	15,680	14,670	15,100	14,460	12,710	11,770
Range (above ave.	250	190	320	110	180	90	120	160	190	300	310	510	840
(below ave.	990	840	340	120	210	130	120	130	610	540	220	380	610
Total range	1,240	1,030	660	230	390	220	240	290	800	840	530	890	1,450
Dry, mineral-matter-free B. t. u.:													
Maximum	15,340	15,640	15,720	15,890	15,920	15,840	15,970	15,860	15,250	15,620	14,800	13,610	13,260
Average	15,130	15,470	15,470	15,800	15,800	15,750	15,840	15,750	15,100	15,480	14,520	13,110	12,460
Minimum	14,190	14,620	15,220	15,670	15,570	15,620	15,740	15,620	14,590	14,940	14,270	12,730	11,840
Range (above ave.	210	170	250	90	120	90	130	110	150	140	280	500	800
(below ave.	940	850	250	130	230	130	100	130	510	540	250	380	620
Total range	1,150	1,020	500	220	350	220	230	240	660	680	530	880	1,420

TABLE III. - Average dry volatile matter, moisture- and ash-free B.t.u., and mineral-matter-free B.t.u. for various coal seams and areas.

(Values marked (b) are averages of only 20 to 60 samples from sources other than the Bureau of Mines; those marked (c) are averages from these sources of less than 20 samples.)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Alabama	Bibb	Woodstock (c)	36.0	15,350	15,480
		Thompson	36.6	14,930	15,050
		Clark	35.8	15,210	15,330
	Blount	Black Creek	31.7	15,420	15,500
	Fayette	Jagger	35.0	14,800	14,980
	Jefferson	Mary Lee	28.4	15,320	15,530
		Black Creek	32.7	15,440	15,520
		Jefferson	34.2	15,310	15,530
		Blue Creek	25.7	15,560	15,730
		Pratt	30.6	15,480	15,650
	Marion	Black Creek	39.3	14,870	14,970
	Shelby	Montevallo	39.5	15,020	15,130
		Gholson	36.6	15,190	15,260
	St.Clair	Mammoth	34.4	15,170	15,330
		Harkness	35.1	15,150	15,370
	Walker	Mary Lee	32.1	14,680	14,890
		Black Creek	37.3	15,090	15,170
Arkansas					
	Franklin	Denning	15.2	15,550	15,700
	Johnson	Hartshorne	12.3	15,420	15,640
		Anthracite (c)	11.2	15,480	15,650
	Logan	Paris	18.2	15,560	15,790
	Pope	Hartshorne	12.0	15,370	15,590
	Sebastian	do.	17.5	15,530	15,700
		Excelsior	18.0	15,610	15,720

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TABLE III (continued)
(page 2)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Colorado	Boulder	Various	38.5	13,190	13,270
	Delta	do.	39.2	13,750	13,870
	El Paso	do.	41.5	12,560	12,660
	Fremont	do.	39.0	13,850	13,980
	Gunnison	High-rank coals Anthr., semi-anthr., low-vol.	7.8	15,350	15,490
		Low-rank coals High-vol.A, High-vol.B, High-vol.C, Subbit. A	40.2	14,350	14,430
	Huerfano	Various	39.2	14,220	14,380
	Jackson		40.9	13,030	13,120
	Jefferson		40.3	12,690	12,790
	Las Animas	Various	34.7	15,050	15,240
	Routt	do.	39.9	13,750	13,840
	Weld	do.	38.1	13,240	13,330
Illinois	Bond	No. 6	37.6	14,160	14,490
	Bureau	No. 2	41.5	14,320	14,640
	Christian	No. 6	41.2	14,170	14,510
	Clinton	No. 6	39.8	14,000	14,310
	Franklin	No. 6	36.5	14,510	14,660
	Fulton	No. 5	40.4	14,350	14,680
		No. 6	41.0	14,380	14,590

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TABLE III (continued)
(page 3)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Illinois	Henry	No. 2	43.4	14,180	14,460
		No. 1	42.3	14,410	14,800
	Jackson	No. 6	38.1	14,400	14,670
	Knox	No. 1	43.5	14,470	14,840
		No. 6 (c)	38.8	13,970	14,210
	La Salle	No. 2	42.7	14,310	14,740
	Macon	No. 5	40.0	14,130	14,440
	Macoupin	No. 6	41.5	14,070	14,400
	Madison	No. 6	41.5	14,200	14,520
	Marion	No. 6	40.5	14,340	14,630
	Montgomery	No. 6	40.6	14,070	14,390
	Peoria	No. 5	39.9	14,400	14,730
	Perry	No. 6	38.0	14,310	14,490
		No. 6	38.0	14,310	14,600
	Randolph	No. 6	38.8	14,130	14,430
	Saline	No. 5	36.3	14,680	14,880
	Sangamon	No. 5	39.5	14,210	14,570
	St. Clair	No. 6	40.2	14,200	14,540
	Tazewell	No. 5	39.2	14,170	14,440
	Vermilion	No. 6 (c)	37.4	14,260	14,500
		No. 7	42.2	14,470	14,790
	Washington	No. 6	38.9	14,390	14,730
	Will	No. 2 (b)	43.1	14,430	14,670
	Williamson	No. 6	35.3	14,530	14,710
	Woodford	No. 2 (c)	42.4	14,550	14,840

TABLE III (continued)
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State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Indiana	Clay	Brazil Block	37.3	14,730	14,870
		No. 3	42.6	14,480	14,840
	Gibson	No. 5	40.9	14,500	14,770
	Greene	No. 4	41.2	14,610	14,790
		No. 5	42.6	14,440	14,730
		No. 6	39.5	14,460	14,730
	Knox	No. 5	41.2	14,510	14,810
	Pike	No. 5	41.1	14,430	14,710
	Sullivan	No. 6	40.6	14,580	14,790
		No. 5	38.7	14,500	14,650
		No. 4	40.8	14,390	14,580
	Vermilion	No. 4	39.0	14,610	14,770
		No. 5	43.6	14,550	14,850
		No. 6	42.7	14,450	14,690
	Vigo	No. 3	43.5	14,530	14,810
		No. 4	39.7	14,500	14,680
		No. 5	42.3	14,440	14,750
	Warrick	No. 5	41.6	14,370	14,660
Iowa	Appanoose	Mystic	40.6	14,090	14,440
		Centerville(c)	40.8	14.100	14.470
	Boone	No. 3 (c)	41.3	14.100	14.530
			40.3	13,730	14,230
	Dallas	No. 3 (c)	39.5	14,110	14,500
			40.2	14,380	14,840
	Lucas		39.5	14,240	14,760
		No. 3 (c)	39.9	14,310	14,720

TABLE III (continued)
(page 5)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Iowa	Marion		40.7	14,140	14,510
		Mammoth (c)	40.7	14,400	14,740
	Polk	No. 3	39.6	14,310	14,820
	Warren		42.3	14,430	14,820
Kansas	Cherokee	In Cherokee shale	36.7	15,120	15,410
		Cherokee (c)	39.4	14,970	15,310
		Mineral (c)	38.7	15,080	15,370
	Crawford	In Cherokee shale	36.6	15,120	15,460
		Cherokee (b)	36.6	15,000	15,380
		Baxter (c)	37.8	15,000	15,380
		Mineral (c)	38.2	15,070	15,350
		Weir-Cherokee (c)	32.9	14,830	15,190
	Leavenworth	Leavenworth	39.9	14,430	14,780
Kentucky	Bell	Lower Hignite	38.8	14,940	15,020
		Straight Creek	39.1	15,060	15,150
		Mason	38.6	15,000	15,100
		Harlan (c)	36.8	14,990	15,070
		Creech (c)	36.8	15,080	15,190
	Christian	No. 6	39.7	14,580	14,740

TABLE III (continued)
(page 6)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Kentucky	Clay	Horse Creek	37.9	15,130	15,270
	Floyd	Elkhorn No. 1	38.3	14,920	15,020
		Elkhorn No. 2	37.6	14,950	15,060
		Elkhorn No. 3	37.5	14,940	15,020
		Miller's Creek (c)	36.7	14,880	14,960
	Harlan	Harlan	38.1	15,070	15,160
		No. 5 (b)	37.4	15,220	15,280
		High Splint	39.2	14,790	14,870
		Darby No. 5(b)	37.6	15,040	15,110
		Kellioka (b)	37.1	14,970	15,100
		Wallins	39.3	14,980	15,060
	Henderson	No. 9	39.6	14,350	14,690
	Hopkins	No. 6	39.0	14,640	14,870
		No. 9	39.5	14,560	14,850
		No. 11	39.8	14,550	14,840
	Johnson	Miller's Creek	39.1	14,720	14,820
	Knox	Dean	37.5	14,830	14,960
	Letcher	Hazard No. 4	36.6	14,980	15,100
		Elkhorn	37.5	15,120	15,180
	McCreary	No. 1	37.5	14,890	15,090
		No. 1½	37.1	14,860	14,970
	Martin	No. 2 Gas (b)	38.8	15,010	15,190
		Thacker (c)	40.5	14,900	15,090
	Muhlenberg	No. 9	39.5	14,580	14,860
	Ohio	No. 9	39.8	14,460	14,730

TABLE III (continued)
(page 7)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Kentucky	Perry	Hazard No. 4	38.7	15,010	15,090
		Hazard No. 7	37.3	14,960	15,060
	Pike	Pond Creek	34.4	15,150	15,260
		Alma (c)	35.9	15,250	15,350
	Webster	No. 9	38.5	14,770	15,060
	Whitley	Jellico	37.6	14,800	14,900
		Blue Gem	36.7	14,610	14,770
Maryland	Allegany	Pittsburgh	18.7	15,630	15,790
		Tyson	20.2	15,560	15,710
		Bakerstown	16.2	15,480	15,770
	Garrett	Lower Kittanning	22.9	15,580	15,900
		Upper Kittanning	28.7	15,350	15,680
Michigan	Tuscola	Verne (c)	40.3	14,860	15,150
Missouri	Adair	Bevier	41.0	14,220	14,550
	Barton	Cherokee	35.5	15,020	15,300
	Bates	Rich Hill (c)	38.9	14,470	14,940
	Henry	Tebo	41.8	14.230	14.610
	Lafayette	Lexington (c)	39.0	14.250	14.600
			37.5	14,000	14,410
	Randolph	Bevier	40.6	14,430	14,750

TABLE III (continued)
(page 8)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Montana	Eastern Lignite fields		40.0	12,000	12,140
	Havre field		36.8	12,730	12,910
	Lewiston field		36.7	13,200	13,380
	Red Lodge field		38.1	13,580	13,780
	Rosebud field		39.1	12,670	12,800
	Roundup - Bull Mt. field		35.6	13,830	13,960
New Mexico	Colfax	Raton	36.8	15,020	15,220
	McKinley	Various	42.5	14,060	14,190
	Santa Fe	White-ash anthr.	5.8	14,980	15,130
		High-vol. A	33.0	15,010	15,210
North Dakota	Burleigh		43.9	12,170	12,280
	Divide		39.9	12,590	12,730
	Mercer		39.1	12,210	12,360
	McLean	Lignitic	42.1	12,130	12,240
	Ward	do.	38.2	11,860	12,020

TABLE III (continued)
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State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Ohio	Athens	Pittsburgh No.8	42.1	14,320	14,560
		No. 7	39.3	14,290	14,470
		No. 6	38.0	14,370	14,540
	Belmont	Pittsburgh No. 8	41.9	14,790	15,050
	Guernsey	No. 7	37.6	14,730	14,900
	Harrison	Pittsburgh No. 8	38.6	14,770	15,010
		Middle Kittanning (c)	39.6	14,890	15,120
	Hocking	No. 6	39.1	14,280	14,480
	Jackson	No. 2	36.3	14,200	14,290
	Jefferson	Pittsburgh No. 8	38.5	14,750	14,980
		No. 6 (c)	38.2	14,910	15,150
	Morgan	No. 6	41.2	14,430	14,610
	Muskingum	No. 6	41.9	14,440	14,670
	Noble	No. 6 (c)	-	14,770	15,040
		No. 7	37.6	14,650	14,890
	Perry	No. 6	39.0	14,290	14,480
	Tuscarawas	No. 6	41.8	14,640	14,900
Oklahoma	Haskell	Hartshorne	22.9	15,470	15,600
	La Flore	Semianthr. (c)	17.3	15,670	15,810
		Hartshorne	18.0	15,470	15,620
	Okmulgee	Henryetta	37.4	14,860	14,960
	Pittsburg	McAlester	36.7	15,050	15,160
	Tulsa	Broken Arrow(c)	38.6	14,880	15,140
	Wagoner	Dawson	35.4	14,910	15,030

TABLE III (continued)
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State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Pennsylvania	Allegheny	Pittsburgh	36.2	15,130	15,290
		Thick Freeport	35.9	15,200	15,380
		Upper Freeport	36.2	15,230	15,390
	Armstrong	Lower Kittanning	38.5	15,160	15,410
		Upper Freeport	34.8	15,140	15,380
	Bedford	Barnett (c)	16.5	15,640	15,790
	Butler	Upper Freeport	35.3	15,150	15,340
		Middle Kittanning	37.4	15,070	15,250
	Cambria	B Seam	19.1	15,530	15,700
		D Seam	18.5	15,650	15,900
			23.9	15,650	15,860
		C. Prime	17.7	15,640	15,860
			23.8	15,640	15,820
		E Seam	18.5	15,660	15,850
			26.0	15,660	15,850
	Center	Lower Kittanning	24.8	15,480	15,680
	Clarion	do.	38.4	15,050	15,280
	Clearfield	E Seam	25.9	15,590	15,770
		B Seam	22.2	15,640	15,840
		D Seam	24.3	15,630	15,790
	Fayette	Pittsburgh	33.8	15,340	15,490
	Greene	do.	35.4	15,120	15,290
		Sewickley	36.4	15,090	15,270
	Huntingdon	Fulton	16.4	15,600	15,790
		Barnett (c)	18.7	15,780	15,950
	Indiana	Upper Freeport	29.8	15,420	15,620
		Lower Freeport	29.9	15,520	15,690

TABLE III (continued)
(page 11)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Pennsylvania	Jefferson	Lower Freeport	31.9	15,390	15,580
	Somerset	B	16.9	15,620	15,830
		C. Prime	17.0	15,630	15,840
	Tioga	Bloss	21.4	15,500	15,700
	Washington	Pittsburgh	36.8	15,220	15,360
	Westmoreland	do.	24.9	15,520	15,780
			34.2	15,250	15,430
		Upper Freeport	24.7	15,510	15,780
			34.4	15,210	15,420
Tennessee	Anderson	Pee Wee	38.8	15,080	15,180
		Dean	37.7	14,970	15,220
	Campbell	Jellico	38.0	15,070	15,170
		Pee Wee	37.1	14,850	14,950
	Claiborne	Jellico	38.5	14,980	15,080
		Mason	37.3	14,890	15,060
	Grundy	Sewanee	30.7	15,120	15,270
	Marion	do.	29.4	15,250	15,400
Texas	Bastrop		43.5	12,710	12,910
	Milam		43.8	12,690	12,880
Utah	Carbon	Mined at Sunnyside, Utah	39.8	14,690	14,790
		Various, except from Sunnyside	44.2	14,390	14,490

TABLE III (continued)
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State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Virginia	Buchanan	Clintwood	32.1	15,520	15,660
		Jewell	21.4	15,820	15,880
		Cary	22.8	15,700	15,870
	Dickenson	Upper Banner	30.6	15,650	15,770
		Splashdam	31.3	15,550	15,700
	Lee	High Splint (b)	38.5	14,940	15,040
		Low Splint	37.5	15,130	15,250
		Blue Diamond No. 10 (c)	36.7	14,940	15,040
		No. 5	36.9	15,120	15,200
	Montgomery	Brushy Mt.	12.3	15,080	15,470
	Pulaski	Langhorne	11.2	15,280	15,600
	Russell	Upper Banner	36.0	15,360	15,480
	Tazewell	Raven Red Ash	32.1	15,550	15,660
		Jewell	23.2	15,770	15,850
		Pocahontas No.5	21.7	15,710	15,820
		Pocahontas No.3	20.6	15,770	15,850
	Wise	High Splint	36.3	15,220	15,340
		Imboden	35.2	15,190	15,300
		Taggart and Marker	37.2	15,360	15,420
Washington	King	McKay	42.3	13,930	14,000
	Kittitas	Roslyn	38.8	14,720	14,930
	Pierce	Med.-vol. coals	23.1	15,500	15,780
		High-vol. coals	33.4	15,220	15,460
	Thurston	Subbit. B	42.0	12,940	13,100

TABLE III (continued)
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State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
West Virginia	Barbour	Pittsburgh	38.0	15,290	15,490
		Kittanning	29.9	15,350	15,560
	Boone	Campbells Creek	36.2	14,970	15,100
		Dorothy	35.9	15,350	15,440
		Coalburg	35.2	15,110	15,300
		Hernshaw	35.7	15,410	15,510
		No. 5 Block	35.0	15,090	15,210
	Brooke	Pittsburgh No.8	38.4	14,770	14,980
	Clay	No. 5 Block	36.9	15,120	15,260
	Fayette	Sewell	23.1	15,620	15,710
		Fire Creek	21.5	15,640	15,760
		Eagle	32.0	15,610	15,710
		No. 2 Gas	34.6	15,340	15,470
		Powellton	33.3	15,410	15,510
	Greenbrier	Sewell	25.8	15,570	15,690
	Harrison	Pittsburgh	39.9	15,130	15,350
	Kanawha	Powellton	33.5	15,490	15,550
		Coalburg	35.4	15,120	15,250
		Eagle	34.9	15,430	15,520
		Winifrede	35.1	15,270	15,360
		Lewiston	37.3	15,150	15,260
	Logan	Eagle	33.5	15,310	15,430
		Chilton	35.3	15,240	15,350
		Island Creek	36.4	15,210	15,360
	McDowell	Pocahontas No.3	18.1	15,820	15,930
		Bradshaw	22.7	15,790	15,900
		Pocahontas No.4	16.2	15,740	15,850
		Pocahontas No.5	22.2	15,770	15,890
		Beckley	17.3	15,680	15,840
	Marion	Pittsburgh	37.9	15,220	15,360
	Mercer	Pocahontas No.3	17.9	15,620	15,720

TABLE III (continued)
(page 14)

State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
West Virginia	Mineral	Bakerstown	15.9	15,550	15,800
	Mingo	Winifrede	37.4	15,070	15,180
		Pond Creek	32.6	15,320	15,430
		Cedar Grove	36.5	15,290	15,410
	Monongalia	Pittsburgh	36.0	15,260	15,490
		Sewickley	36.3	15,100	15,370
	Ohio	Pittsburgh No.8	40.9	14,770	15,040
	Preston	Kittanning	23.5	15,420	15,650
		Bakerstown	29.5	15,510	15,690
	Raleigh	Eagle	29.6	15,570	15,650
		Pocahontas No.3	16.8	15,700	15,830
		Dorothy	33.9	15,400	15,500
		Beckley	17.6	15,660	15,760
		Sewell	21.2	15,670	15,780
		Fire Creek	16.9	15,650	15,780
	Randolph	Sewell	29.8	15,500	15,620
		Kittanning	30.3	15,430	15,640
	Taylor	Pittsburgh	38.6	15,330	15,530
	Tucker	Lower Kittanning (c)	26.4	15,620	15,770
	Webster	Sewell	31.5	15,460	15,560
	Wyoming	Pocahontas No.3	17.5	15,620	15,740
		Pocahontas No.6	18.3	15,700	15,800
		Beckley	18.7	15,570	15,690
		Sewell	22.8	15,780	15,870
Wyoming	Carbon	High-vol. C Bit., subbit.A, subbit. B	42.2	13,500	13,610
	Freemont	Subbit. B	41.9	13,230	13,330

TABLE III (continued)
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State	County	Seam	Volatile (dry)	Moisture- and ash-free B.t.u.	Dry, mineral-matter-free B.t.u.
Wyoming	Lincoln	High-vol. A, High-vol. B	40.8	14,360	14,460
		Subbit. B	44.7	13,350	13,420
	Sheridan	Subbit. B and C	42.1	12,910	12,990
	Sweetwater	High-vol. B, High-vol. C, Subbit. A	42.0	13,960	14,040